Sustainability Project Fund Application Form

Project Title: From Waste to Clean Energy: McGill Community Biodiesel Production (Phase I)

Budget Requested: $1500.00

Applicant/Project Leader: Matthew Bohan
Faculty/Department: Faculty of Engineering, Department of Materials Engineering (current)
Faculty of Science, Department of Chemistry (former)
Email: matthew.bohan@mail.mcgill.ca
Daytime Phone: (978)-660-7433

Project Team:

Advisors:

Professor Jean-Philip Lumb, *Department of Chemistry*, jean-philip.lumb@mcgill.ca
Laboratory Coordinator Mitchell Huot, *Department of Chemistry,* mitchell.huot@mail.mcgill.ca

Students:

Alan Blayney, *Department of Chemistry*, alan.blayney@mail.mcgill.ca
Adriana Zapata Lango, *Department of Economics,* adriana.zapata@mail.mcgill.ca
Charles Alexander, *Department of Chemical Engineering,* charles.alexander@mail.mcgill.ca
Harrison Wood, *Department of Political Science,* harrison.wood@mail.mcgill.ca
Christoph Doerfelt, *Department of Materials Engineering,* christoph.doerfelt@mail.mcgill.ca

---

I. Project Overview

Project description and objectives:

Background:

The McGill Food and Dining Serves (MFDS) produces approximately 14000 liters of waste vegetable oil (WVO) per annum. Sanimax pays MFDS a nominal reward to collect the waste, from which it profits by refinement into animal feed products. Executive Chef Oliver de Volpi acknowledges the convenience of this service but recognizes the loss of a valuable commodity: WVO contains an amount of chemical energy comparable to crude oil. While unsuitable for direct use in its native form, a simple chemical reaction transforms WVO into *biodiesel*, an ASTM International regulated alternative to fossil diesel fuel. Biodiesel offers many benefits over fossil diesel and combusts in conventional diesel engines without modification. Student-organized, small-scale production of biodiesel has successfully fuelled campus fleets at other prominent research universities: University of Colorado Boulder, Clemson University, Massachusetts Institute of Technology, University of Calgary, and many others. Development of a biodiesel initiative will bolster McGill as a leader in scientific research and demonstrate its commitment to sustainability.

This application seeks funding for Phase I of the project, a thorough investigation into the feasibility of biodiesel production at McGill for use in campus vehicles. If Phase I is successful, Phase II will seek further funding to implement a self-sustaining, full-scale biodiesel production that will significantly enrich the culture of sustainability at McGill.

The following criteria will be addressed in Phase I:

1. **Logistics, operations, and utilization in the McGill community**
   A reliable supply chain system must be implemented. Requirements include: reliable pickup of WVO from MFDS cafeterias, safe transportation of WVO to plant location, and safe handling and storage of all feedstocks and products.

   a. **Plant location and storage**
      Macdonald campus is an ideal location due to relative abundance of space and community support of agribusiness. There is also potential to extract additional feedstock oil from crop waste by cold press technology. A suitable site will have electricity, running water, and adequate ventilation.
      - *Investigate potential plant locations (mobile plant?)*
      - *Evaluate site specific safety compliance regulations*
      - *Consider impact of local community and environment*
      - *Estimated plant size: 200-liter capacity, 100 ft^2 floor space required*

   b. **Pickup and transportation of waste oil**
      Christian Bouchard, Manager of Hazardous Waste Management (HWM), has offered to support this project in its early stages by providing access to HWM pickup trucks. In addition, empty HWM trucks currently travel to Macdonald campus bimonthly to pick up chemical waste and could easily transport WVO on these trips without additional cost or environmental impact.
      - *Negotiate long-term contract with HWM for WVO transportation*

   c. **Utilization in Facilities vehicle fleet**
      Peter Knox, Supervisor of Facilities Operations and Development, has left open the possibility for use of biodiesel in the Facilities fleet.
      - *Consider potential risks of biodiesel use in Facilities vehicles*
      - *Consult auto and equipment manufacturer warranties*
      - *Identify ideal candidate vehicles for biodiesel use from Facilities fleet*

2. **Technical proof of concept**
   The classic method of producing biodiesel from vegetable oil is a *transesterification* reaction, which requires methanol and sodium hydroxide and produces a glycerine waste product. This method will serve as the initial platform.

   a. **Laboratory scale:**
      - *Demonstrate ability to produce ASTM D6751 compliant biodiesel*
      - *Optimize reaction parameters*
      - *Determine reaction yield*
      - *Develop in-house quality control procedures*
      - *Analyze glycerine byproduct and investigate reuse (soap?) or disposal options*
      - ***Corroborate quality control with external analytical laboratory***

   b. **Pilot scale:**
      - *Demonstrate large scale production of biodiesel*
      - *Design and optimize process and plant size*
      - *Investigate dry washing alternative to washing with water*
      - *Construct **1-liter pilot plant** (to later be publically displayed)*

- *Analyze process inputs and outputs, feedstocks and wastestreams*
- *Measure electrical energy input*

3. Formulation of "business" plan for full-scale production

- While not formally a business, the feasibility of this project will be held to the standard of a profitable business (i.e., "sink or swim") in order to ensure future self-sufficiency.
- Experimental results from laboratory experiments will be analyzed to determine accurate estimates of capital costs and operational expenditures, including chemical, electricity, and labour costs. A financial forecast will be generated.
- These parameters will be fit into a business model that will indicate the breakeven point and the payback period**,** the length of time for the return on investment to cover the initial investment.
- Ideally, the mature project will be incorporated into the budgeting of an existing department (e.g., Facilities).
- This business plan will constitute the final report for Part I, and will serve as the roadmap for Part II.

Project eligibility:

How will the project contribute to building a culture of sustainability on campus?

- **Integration with education and research**
  Prof. Lumb and Mr. Huot are interested in integrating this project into the curriculum of the Department of Chemistry. Prof. Lumb foresees the creation of a new course that emphasizes chemistry relating to biomass conversion, his area of expertise. Mr. Huot plans to integrate elements of biodiesel production into existing laboratory courses, such as **CHEM 392: Integrated Inorganic/Organic Laboratory**, which he currently coordinates. In fact, the laboratory-scale research will begin as a "synthesis project" conducted by Alan for this course. The Project Team is excited to be involved however possible in these pursuits and will also entertain student volunteers, honours project students, and design project students. Additionally, a biodiesel plant could serve as a valuable tool to researchers from a variety of disciplines.
- **Affiliation with other student sustainability and/or energy groups**
  In its infancy, this project has been chaperoned by the **McGill Energy Project (MEP)** and specifically by Will Agnew, which has generated successful networking of interested students and facilitated many vital connections. Collaboration and participation in campus sustainability events, such as the McGill Sustainability Symposium, will be a continued mode of outreach.

Provide any supporting information that demonstrates a need for the project on campus.

- **Reduction of emissions from McGill community vehicles**
  The Montréal Community Sustainable Development Plan 2010–2015 mandates that the city reduce greenhouse gas emissions to 30% of 1990 levels by 2020 and has many other stipulations pertaining to air quality. Biodiesel benefits from a significant direct reduction of several regulated emissions relative to petroleum diesel: particulate matter (PM), carbon monoxide (CO), and total hydrocarbons (THC). While direct carbon dioxide (CO_2) emission reductions are not observed, biodiesel is considered carbon neutral, emitting the same amount of carbon captured by the plant from which it is derived. Employing 14000 liters of biodiesel per year would offset approximately 38 metric tons of carbon dioxide (assumption: 1 liter diesel = 2.68 kg CO_2). See Figure 1 in the appendix for more information on emission reductions.

- **Waste-to-energy**
  This project will prevent export of approximately 13000 kg of liquid waste annually and the subsequent consumption of an estimated 14000 liters of diesel fuel will be avoided. Simultaneous reductions of waste generation and fossil fuel consumption will create a more autonomous McGill that relies less on external resources.

Timeframe/Milestones:

Phase I Deliverables: March 1 – August 31 2012

March 15: -Initial lab-scale feedstock analysis, production, and optimization
June 1: -Lab-scale biodiesel batch sent for professional testing
June 15: -Pilot plant designed
-Projected supply & usage schedules (WVO→biodiesel→Macdonald campus vehicles) designed and corroborated with all parties
July 1: -Pilot plant constructed in chemistry lab
July 15: -Pilot-scale production begun, quality control testing
August 31: -Site located for full-scale production
-Projected transportation schedule (via HWM) integrated with supply & usage schedules
-Submission of budget & business model for Phase II

Performance indicators:

- American Society for Testing and Materials (ASTM) International D6751 certification
- Production of 1-liter batch of biodiesel via pilot plant
- Formal agreements with: MFDS (WVO), HWM (transportation), Facilities (utilization)
- Acquisition of facility for biodiesel plant
- Final report/"business" plan proving feasibility of full-scale production

Stakeholders:

- **Jean-Phillip Lumb**, *Professor,* Department of Chemistry
  Prof. Lumb is an expert of sustainable chemistry. His research involves using chemistry to find practical uses for biomass wastestreams and is highly relevant to this project.
- **Mitchell Huot,** *Laboratory Coordinator*, Department of Chemistry
  Mr. Huot is a firm believer in progressive education. To this end, he has offered access lab space, chemical reagents, and instruments to aid in the advancement of the project.
- **Oliver de Volpi**, *Executive Chef,* McGill Food and Dining Services
  Mr. de Volpi is a strong supporter of the project and has generously offered to donate the VWO generated by the cafeterias at no cost.
- **Peter Knox,** *Supervisor*, Facilities Operations and Development
  Mr. Knox has been contacted and confirmed the possibility of biodiesel ulilization in Facilities vehicles pending more information.
- **Christian Bouchard,** *Manager,* Hazardous Waste Management
  Mr. Bouchard has experience transporting WVO and offered the interim use of HWM pickup trucks to transport WVO. A long-term solution is possible, but must be negotiated.
- **Wayne Wood,** *Associate Director,* Environmental Health & Safety
  Mr. Wood gave verbal approval of the project, simply requesting a share of biodiesel to fill his own VW TDI car. His consultation will ensure compliance of safety protocols.

II. Project Implementation

Tasks and Responsibilities:

Type of Activity – Task	Anticipated Timeframe	Members in Charge
Lab-scale production & testing	March 1 – June 1	Alan, Christoph
Pilot plant construction & production	May 1 – June 15	Alan, Charles, Matt
Sites location (storage & production)	March 1 – August 31	Matt
Supply negotations & logistics	March 1 – August 31	Harrison
Usage negotiations & logistics	March 1 – August 31	Harrison
Transportation logistics	March 1 – August 31	Matt
Budget & sustainable business model	April 1 – August 31	Adriana

III. Financials

- Critical Date: June 1

Detailed expenses:

Expense Description	Estimated Cost
ASTM D6751 Biodiesel Test, Maxxam Analytics	$1500.00

Detailed revenues:

Revenue Source	Amount Requested	Confirmed?
Sustainability Projects Fund	$1500.00	No

IV. Additional information:

- I, Matthew Bohan, am a graduate of the Department of Chemistry. Like many undergraduate students, I struggled to understand how my studies would translate into the “real world.” I strongly believe involvement in a project that applied principles derived in the classroom to solve a tangible problem would have been a rewarding educational experience for me. If part of the curriculum, this project could attract a wider selection of talented to young minds to chemistry, a field commonly dismissed as boring.
- In addition to a formal background in chemistry and engineering, I possess a working knowledge of automotive mechanics. My previous work on a SPF initiative—the laboratory chemical waste minimization project—spawned the idea for this project. Laboratory waste is difficult to reuse because it is often mixed with other wastestreams or is produced in quantities too small for viable processing. Reuse of WVO to produce usable, clean energy presents a unique opportunity for McGill to recycle a waste product.
- The Project Team is a diverse group of upper-year undergraduate and graduate McGill students who are very knowledgeable in their fields of study. The commitment of the Project Team was exemplified when no one requested compensation for their work on this part of the project. It is a group only looking to profit in terms of interest, learning experience, and involvement in a good cause. While Charles and Adriana will be graduating this May, the remainder will continue studies at McGill for a minimum of 1-2 years. The response from many other students interested in helping with the project is promising to its future.

Appendix

Figure 1: Percent change in emissions for nitrous oxide (NO_x), particular matter (PM), carbon monoxide (CO), and hydrocarbon (HC) as a function of biodiesel blend. NO_x exhibits a marginal increase in percent emissions due to the relative higher combustion temperature of biodiesel, while PM, CO, and HC show significant reductions, (Source: Biodiesel Basics and Beyond).

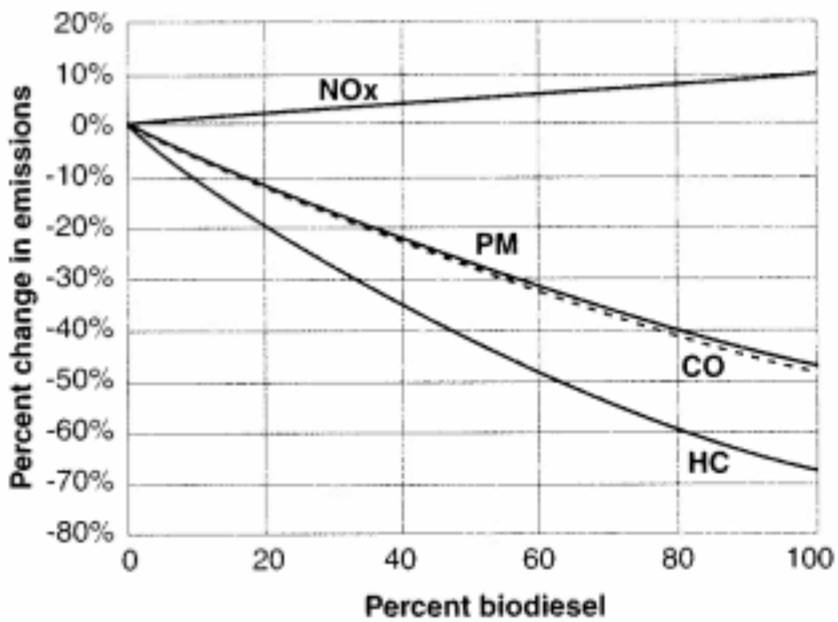


Figure 3.2-5. A study conducted by the U.S. EPA[7] found that tests conducted using various blends of biodiesel with No. 2-D fuel on a highway truck, an urban bus, and a full-sized pickup truck showed these emissions reductions compared with 100% No. 2-D fuel. (Data source: U.S. Environmental Protection Agency)

Figure 2: Impurity limit specifications for ASTM D6751 standard (Source: Biodiesel Basics and Beyond).

Appendix 1
ASTM D 6751

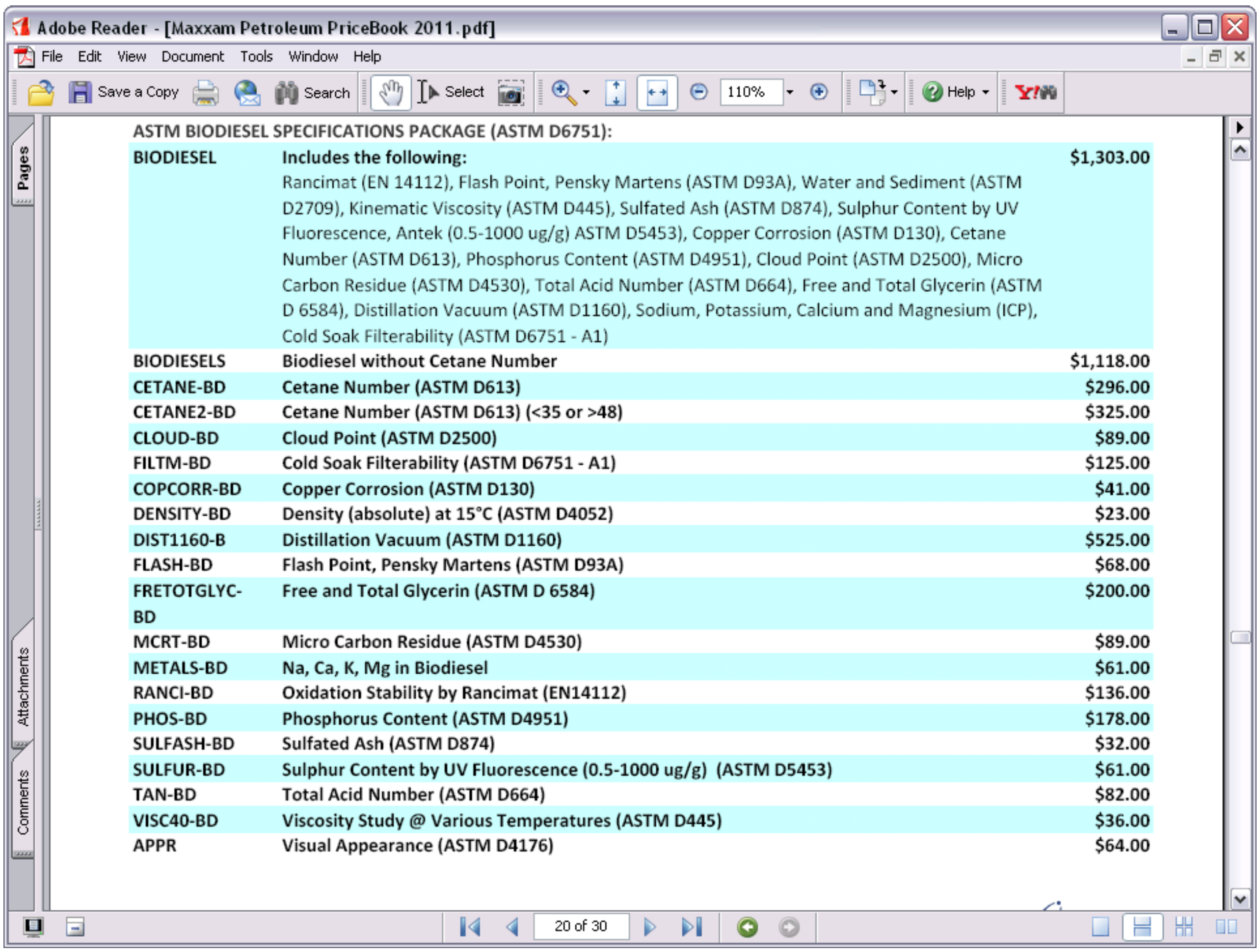
Table 1 Detailed Requirements for Biodiesel (B100)[A]

Property	Test Method[B]	Limits	Units
Flash point (closed cup)	D 93	130.0 min	°C
Water and sediment	D 2709	0.050 max	% volume
Kinematic viscosity, 40°C	D 445	1.9-6.0[C]	mm^2/s
Sulfated ash	D 874	0.020 max	% mass
Sulfur[D]	D 5453	0.05 max	% mass
Copper strip corrosion	D 130	No. 3 max	
Cetane number	D 613	47 min.	
Cloud point	D 2500	Report[E]	°C
Carbon residue[F]	D 4530	0.050 max	% mass
Acid number	D 664	0.80 max	mg KOH/g
Free glycerin	D 6584	0.020	% mass
Total glycerin	D 6584	0.240	% mass
Phosphorus content	D 4951	0.001 max	% mass
Distillation temperature Atmospheric equivalent temperature. 90% recovered	D 1160	360 max	°C

[A] To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller and manufacturer.
[B] The test methods indicated are approved referee methods. Other acceptable methods are indicated in 5.1.
[C] See X1.3.1. The 6.0 mm^2/s upper viscosity limit is higher than petrodiesel and should be taken into consideration when blending.
[D] Other sulfur limits can apply in selected areas in the United States and in other countries.
[E] The cloud point of biodiesel is generally higher than petrodiesel and should be taken into consideration when blending.
[F] Carbon residue shall be run on the 100% sample (see 5.1.10).

Table 1 Reprinted, with permission, from D 6751-03a Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

Figure 3: Quote from Maxxam Analytics for ASTM D6751 test. Estimate of $1500.00 includes the total package test ($1303.00) and accounts for tax and shipping costs to Calgary, Alberta. Individual tests can be later performed in the event of failure of isolated tests.



Adobe Reader - [Maxxam Petroleum PriceBook 2011.pdf]

ASTM BIODIESEL SPECIFICATIONS PACKAGE (ASTM D6751):

BIODIESEL	**Includes the following:** Rancimat (EN 14112), Flash Point, Pensky Martens (ASTM D93A), Water and Sediment (ASTM D2709), Kinematic Viscosity (ASTM D445), Sulfated Ash (ASTM D874), Sulphur Content by UV Fluorescence, Antek (0.5-1000 ug/g) ASTM D5453), Copper Corrosion (ASTM D130), Cetane Number (ASTM D613), Phosphorus Content (ASTM D4951), Cloud Point (ASTM D2500), Micro Carbon Residue (ASTM D4530), Total Acid Number (ASTM D664), Free and Total Glycerin (ASTM D 6584), Distillation Vacuum (ASTM D1160), Sodium, Potassium, Calcium and Magnesium (ICP), Cold Soak Filterability (ASTM D6751 - A1)	$1,303.00
BIODIESELS	Biodiesel without Cetane Number	$1,118.00
CETANE-BD	Cetane Number (ASTM D613)	$296.00
CETANE2-BD	Cetane Number (ASTM D613) (<35 or >48)	$325.00
CLOUD-BD	Cloud Point (ASTM D2500)	$89.00
FILTM-BD	Cold Soak Filterability (ASTM D6751 - A1)	$125.00
COPCORR-BD	Copper Corrosion (ASTM D130)	$41.00
DENSITY-BD	Density (absolute) at 15°C (ASTM D4052)	$23.00
DIST1160-B	Distillation Vacuum (ASTM D1160)	$525.00
FLASH-BD	Flash Point, Pensky Martens (ASTM D93A)	$68.00
FRETOTGLYC-BD	Free and Total Glycerin (ASTM D 6584)	$200.00
MCRT-BD	Micro Carbon Residue (ASTM D4530)	$89.00
METALS-BD	Na, Ca, K, Mg in Biodiesel	$61.00
RANCI-BD	Oxidation Stability by Rancimat (EN14112)	$136.00
PHOS-BD	Phosphorus Content (ASTM D4951)	$178.00
SULFASH-BD	Sulfated Ash (ASTM D874)	$32.00
SULFUR-BD	Sulphur Content by UV Fluorescence (0.5-1000 ug/g) (ASTM D5453)	$61.00
TAN-BD	Total Acid Number (ASTM D664)	$82.00
VISC40-BD	Viscosity Study @ Various Temperatures (ASTM D445)	$36.00
APPR	Visual Appearance (ASTM D4176)	$64.00

20 of 30

Figure 4: Example schematic of small-scale biodiesel plant
(Source: Biodiesel Basics and Beyond)